



TECH LIBRARY KAFB, NM
0133945

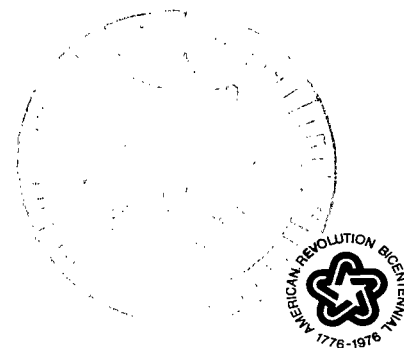
NASA TN D-8162

-LOAN COPY: RETURN TO
AFWAL 70-96-100 LIBRARY
KIRTLAND AFB, NM

LOW-SPEED WIND-TUNNEL INVESTIGATION OF VARIOUS SEGMENTS OF FLIGHT SPOILERS AS TRAILING-VORTEX-ALLEVIATION DEVICES ON A TRANSPORT AIRCRAFT MODEL

Delwin R. Croom

Langley Research Center
Hampton, Va. 23665



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • MARCH 1976



0133945

1. Report No. NASA TN D-8162	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle LOW-SPEED WIND-TUNNEL INVESTIGATION OF VARIOUS SEGMENTS OF FLIGHT SPOILERS AS TRAILING-VORTEX- ALLEVIATION DEVICES ON A TRANSPORT AIRCRAFT MODEL	5. Report Date March 1976	6. Performing Organization Code
7. Author(s) Delwin R. Croom	8. Performing Organization Report No. L-10654	10. Work Unit No. 514-52-01-03
9. Performing Organization Name and Address NASA Langley Research Center Hampton, Va. 23665	11. Contract or Grant No.	13. Type of Report and Period Covered Technical Note
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546	14. Sponsoring Agency Code	
15. Supplementary Notes		
16. Abstract <p>An investigation was made in the Langley V/STOL tunnel to determine, by the trailing wing sensor technique, the effectiveness of various segments of the existing flight spoilers on a transport aircraft model when they were deflected as trailing-vortex-alleviation devices. The four combinations of flight-spoiler segments investigated were effective in reducing the induced rolling moment on the trailing wing model by as much as 40 to 50 percent at distances behind the transport model of from about 7 to 27 transport wing spans, 27 spans being the downstream limit of distances used in this investigation. Results obtained at about 7 wing spans downstream for two of the spoiler configurations indicate that essentially all the reduction in induced rolling moment on the trailing wing model was realized at a spoiler deflection of about 30°.</p>		
17. Key Words (Suggested by Author(s)) Vortex alleviation Trailing-vortex hazard	18. Distribution Statement Unclassified - Unlimited	
		Subject Category 01
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 23
		22. Price* \$3.25

LOW-SPEED WIND-TUNNEL INVESTIGATION
OF VARIOUS SEGMENTS OF FLIGHT SPOILERS AS
TRAILING-VORTEX-ALLEVIATION DEVICES ON A
TRANSPORT AIRCRAFT MODEL

Delwin R. Croom
Langley Research Center

SUMMARY

An investigation was made in the Langley V/STOL tunnel to determine, by the trailing wing sensor technique, the effectiveness of various segments of the existing flight spoilers on a transport aircraft model when they were deflected as trailing-vortex-alleviation devices. The four combinations of flight-spoiler segments investigated were effective in reducing the induced rolling moment on the trailing wing model by as much as 40 to 50 percent at distances behind the transport model of from about 7 to 27 transport wing spans, 27 spans being the downstream limit of distances used in this investigation. Results obtained at about 7 wing spans downstream for two of the spoiler configurations indicate that essentially all the reduction in induced rolling moment on the trailing wing model was realized at a spoiler deflection of about 30° .

INTRODUCTION

The strong vortex wakes generated by large transport aircraft are a potential hazard to smaller aircraft. The National Aeronautics and Space Administration is involved in a program of model tests, flight tests, and theoretical studies to determine the feasibility of reducing this hazard by aerodynamic means.

Results of recent investigations have indicated that the trailing vortex behind an unswept-wing model (ref. 1) or a swept-wing transport model (ref. 2) can be attenuated by a forward-mounted spoiler. The approach used in references 1 and 2 to evaluate the effectiveness of vortex-alleviation devices was to simulate an airplane flying in the trailing vortex of another larger airplane and to make direct measurements of rolling moments induced on the trailing model by the vortex generated by the forward model.

The purpose of the present investigation is to determine the trailing-vortex-alleviation effectiveness of various segments of the existing flight spoilers of a transport aircraft model. The direct-measurement technique described in references 1 and 2 was

used with the trailing wing model from 7 to 27 transport wing spans behind the transport aircraft model. (For a 61-m-span transport aircraft, this would represent a range of downstream distances from about 0.2 to 0.9 nautical mile.)

SYMBOLS

All data are referenced to the wind axes. The pitching-moment coefficients are referenced to the quarter chord of the wing mean aerodynamic chord.

b	wing span, m
C_D	drag coefficient, $\frac{\text{Drag}}{qS_W}$
C_L	lift coefficient, $\frac{\text{Lift}}{qS_W}$
$C_{l,TW}$	trailing wing rolling-moment coefficient, $\frac{\text{Trailing wing rolling moment}}{qS_{TW}b_{TW}}$
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qS_W\bar{c}_W}$
c	wing chord, m
\bar{c}	wing mean aerodynamic chord, m
i_t	horizontal-tail incidence, referred to fuselage reference line (positive direction trailing edge down), deg
l	longitudinal distance in tunnel diffuser, m
q	dynamic pressure, Pa
S	wing area, m ²
X',Y',Z'	system of axes originating at left wing tip of transport aircraft model (see fig. 1)
x',y',z'	longitudinal, lateral, and vertical dimensions measured from trailing edge of left wing tip of transport aircraft model, m
$\Delta y',\Delta z'$	incremental dimensions along Y'- and Z'-axes, m

α angle of attack of fuselage reference line, deg (wing incidence is 2° relative to fuselage reference line)

$\delta_{f,i}$ nominal deflection of inboard segment of flap, deg

$\delta_{f,o}$ nominal deflection of outboard segment of flap, deg

ϕ local streamline angle in tunnel diffuser relative to tunnel center line, deg

Subscripts:

max maximum

TW trailing wing model

W transport aircraft model

MODEL AND APPARATUS

A three-view sketch and the principal geometric characteristics of the 0.03-scale model of a jumbo-jet transport aircraft are shown in figure 1. Figure 2 is a photograph of the transport aircraft model sting mounted in the Langley V/STOL tunnel. The fuselage, empennage, trailing-edge flaps, and leading-edge devices of this model were the same as those used in reference 2. The wing was modified to have flight spoilers typical of this type aircraft. Figure 3 is a sketch showing the location of the flight spoilers on the transport aircraft model. These spoiler segments were constructed as the upper surface of the wing, and when they are deflected, a large gap similar to that of an actual aircraft, is formed immediately forward of the flap element. Photographs of the four combinations of flight-spoiler segments investigated are presented in figure 4.

A photograph and dimensions of the unswept trailing wing model installed on the transverse mechanism are presented in figure 5. The trailing model has a span and aspect ratio typical of small-size transport aircraft.

The test section of the Langley V/STOL tunnel has a height of 4.42 m, a width of 6.63 m, and a length of 14.24 m. The transport aircraft model was sting supported on a six-component strain-gage balance system which measured the forces and moments. The angle of attack was determined from an accelerometer mounted in the fuselage. The trailing model was mounted on a single-component strain-gage roll balance, which was attached to a traverse mechanism capable of moving the model both laterally and vertically. (See

fig. 5.) The lateral and vertical positions of the trailing model were measured by outputs from digital encoders. This entire traverse mechanism could be mounted to the tunnel floor at various tunnel longitudinal positions downstream of the transport aircraft model.

TESTS AND CORRECTIONS

Transport Aircraft Model

All tests were made at a free-stream dynamic pressure in the tunnel test section of 430.9 Pa which corresponds to a velocity of 27.4 m/sec. The Reynolds number for the tests was approximately 4.7×10^5 based on the wing mean aerodynamic chord. Transition strips approximately 0.30 cm wide of No. 60 abrasive grit were placed 2.54 cm back from the leading edge of the wing, whereas natural transition was used elsewhere. The basic longitudinal aerodynamic characteristics were obtained through an angle-of-attack range of approximately -4° to 24° . All tests were made with leading-edge devices extended.

Blockage corrections were applied to the data by the method of reference 3. Jet-boundary corrections to the angle of attack and the drag were applied in accordance with reference 4.

Trailing Wing Model

The trailing wing model and its associated roll-balance system were used as a sensor to measure the induced rolling moment caused by the vortex flow downstream of the transport aircraft model. No transition grit was applied to the trailing model. The trailing model was positioned at a given distance downstream of the transport aircraft model, and the traverse mechanism was positioned laterally and vertically so that the trailing vortex was near the center of the mechanisms. The trailing vortex was probed with the trailing model. A large number of trailing wing rolling-moment data points (usually from 50 to 100) were obtained from the lateral traverses at several vertical locations to ensure good definition of the vortex wake. In addition, certain test conditions were repeated at selected intervals during the test period and the data were found to be repeatable.

Trailing wing rolling-moment measurements were made at downstream scale distances from about 7 to 27 transport wing spans behind the transport aircraft model. All trailing wing rolling-moment data at distances downstream greater than about 7 spans were obtained with the trailing model positioned in the diffuser section of the V/STOL tunnel. These data were reduced to coefficient form based on the dynamic pressure at the trailing wing location. For these tests, the dynamic pressures at the 6.74, 13.48, 20.22, and 26.96 span locations were 430.9, 262.3, 142.9, and 82.5 Pa, respectively. The trailing wing location relative to the wing tip of the transport aircraft model has been corrected to

account for the progressively larger tunnel cross-sectional area in the diffuser section. The corrections to the trailing wing location in the diffuser were made by assuming that the local streamline angles in the tunnel diffuser section are equal to the ratio of the distance from the tunnel center line to the local tunnel half-width or tunnel half-height multiplied by the diffuser half-angle. Corrections to the trailing model locations are as follows: $\Delta y'$ correction or $\Delta z'$ correction = $l \tan \phi$ where $\Delta y'$ correction and $\Delta z'$ correction are, respectively, the corrections to the measured lateral and vertical locations of the trailing model relative to the tip of the transport aircraft model, l is the longitudinal distance in the tunnel diffuser, and ϕ is the local streamline angle in the tunnel diffuser relative to the tunnel center line.

RESULTS AND DISCUSSION

Transport Aircraft Model

The longitudinal aerodynamic characteristics of the transport aircraft model with four combinations of the flight-spoiler segments on each wing deflected symmetrically 45° are presented in figure 6. These data indicate that a nominal lift coefficient for approach ($C_L \approx 1.2$) can be maintained with an angle-of-attack increase of about 2.5° when any pair of the flight-spoiler segments were deflected 45° . It can also be seen in figure 6 that for any of the flight-spoiler combinations investigated, the drag coefficient was increased by about 0.03 and that the maximum lift coefficient was reduced by about 0.15. It was also noted that the pitching-moment curves were more linear and had less pitch-up tendency when the flight spoilers were deflected than when they were retracted.

The effects of deflection angle of flight-spoiler segments 1 and 2 and segments 1 and 4 on the longitudinal aerodynamic characteristics of the transport aircraft model are presented in figures 7 and 8, respectively. For either of these configurations, there is essentially a linear increase in drag with spoiler deflection and about 75 percent of the lift loss at a given angle of attack occurred at a spoiler deflection of only 15° . The pitching-moment curves are more linear when the spoilers are deflected than when they are retracted.

Trailing Wing Model

The maximum rolling-moment coefficient measured by the trailing wing model and the position of this model relative to the left wing tip of the transport aircraft model are presented in figure 9. These measurements were made at several distances from the transport aircraft model with various segments of the flight spoilers deflected 45° . It can be seen in figure 9 that all combinations of flight-spoiler segments investigated were effective in reducing the induced rolling moment on the trailing wing model by as much as

40 to 50 percent at all downstream distances. Of particular interest is the ability of these devices to effect a large reduction in $(C_{l,TW})_{\max}$ (50 to 70 percent) in the relatively near distances (about 7 transport wing spans) downstream of the transport aircraft model.

Flight-spoiler segments 1 and 2 and segments 1 and 4 were tested over a spoiler-deflection range from 0° to 45° with the trailing wing model positioned 7 wing spans behind the transport aircraft model. These data are presented in figure 10. It can be seen that, at this downstream location, essentially all the reduction in induced rolling moment was realized with about 30° of spoiler deflection.

Results of these tests indicate that any combination of two of the flight-spoiler segments tested will reduce the vortex-induced rolling moment on the trailing model and may be effective as a trailing-vortex-alleviation device when used on the transport aircraft.

SUMMARY OF RESULTS

Results have been presented of an investigation in the Langley V/STOL tunnel to determine, by the trailing wing sensor technique, the trailing-vortex-alleviation effectiveness of various segments of the flight spoilers on a transport aircraft model when the segments are deflected as trailing-vortex-alleviation devices.

Four combinations of flight-spoiler segments were investigated and all were effective in reducing the induced rolling moment on the trailing wing model by as much as 40 to 50 percent throughout the range of downstream distances used in this investigation.

Results from tests of two of the flight-spoiler configurations made over a deflection range from 0° to 45° indicate that essentially all the reduction in induced rolling moment on the trailing model was realized at a spoiler deflection of about 30° at a downstream distance of about 7 transport wing spans behind the transport aircraft model.

Langley Research Center
National Aeronautics and Space Administration
Hampton, Va. 23665
January 28, 1976

REFERENCES

1. Croom, Delwin R.: Low-Speed Wind-Tunnel Investigation of Forward-Located Spoilers and Trailing Splines as Trailing-Vortex Hazard-Alleviation Devices on an Aspect-Ratio-8 Wing Model. NASA TM X-3166, 1975.
2. Croom, Delwin R.; and Dunham, R. Earl, Jr.: Low-Speed Wind-Tunnel Investigation of Span Load Alteration, Forward-Located Spoilers, and Splines as Trailing-Vortex-Hazard Alleviation Devices on a Transport Aircraft Model. NASA TN D-8133, 1975.
3. Herriot, John G.: Blockage Corrections for Three-Dimensional-Flow Closed-Throat Wind Tunnels, With Consideration of the Effect of Compressibility. NACA Rep. 995, 1950. (Supersedes NACA RM A7B28.)
4. Gillis, Clarence L.; Polhamus, Edward C.; and Gray, Joseph L., Jr.: Charts for Determining Jet-Boundary Corrections for Complete Models in 7-by 10-Foot Closed Rectangular Wind Tunnels. NACA WR L-123, 1945. (Formerly NACA ARR L5G31.)

Wing

Span, m	1.79
Mean aerodynamic chord, m	0.25
Root chord, m	0.497
Tip chord, m	0.121
Sweepback at quarter chord, deg	37.5
Area, m ²	0.460
Aspect ratio	6.96

Fuselage

Length, m	2.06
-----------	------

Horizontal tail

Span, m	0.664
Area, m ²	0.123
Aspect ratio	3.6

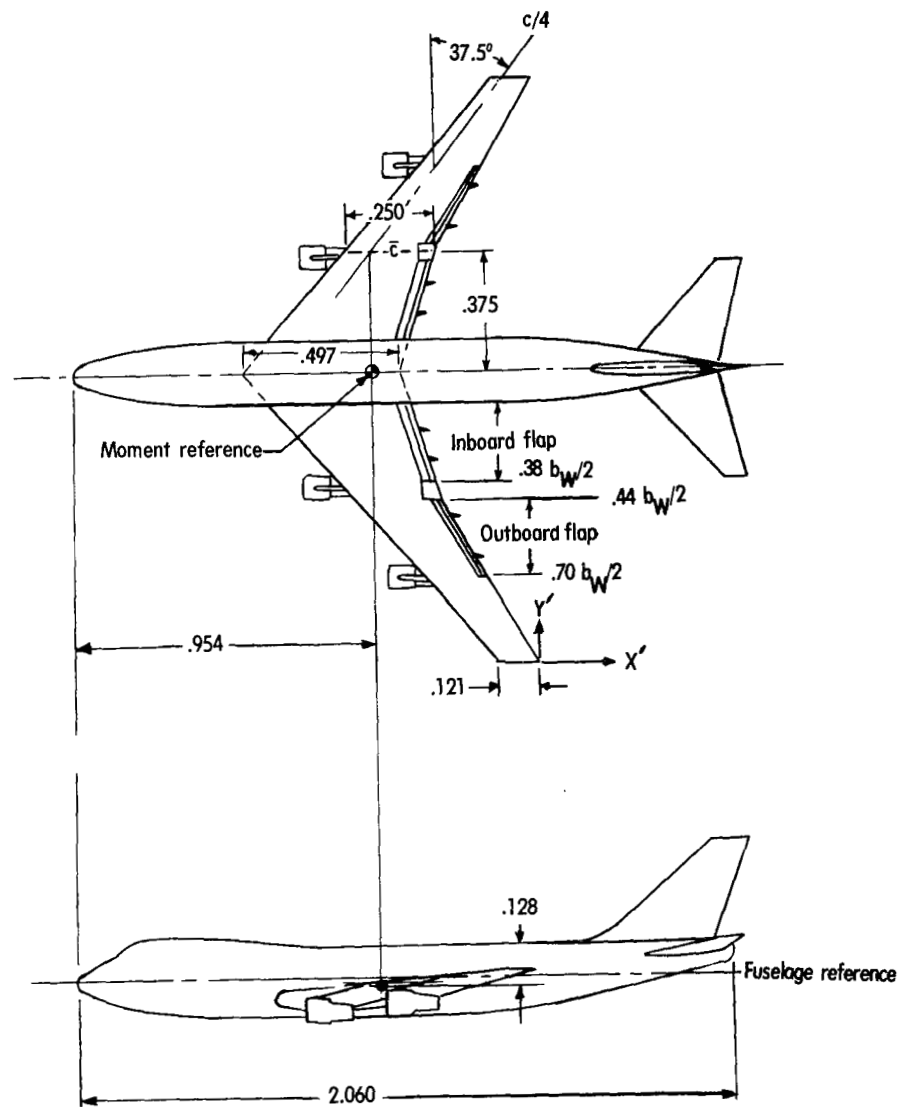
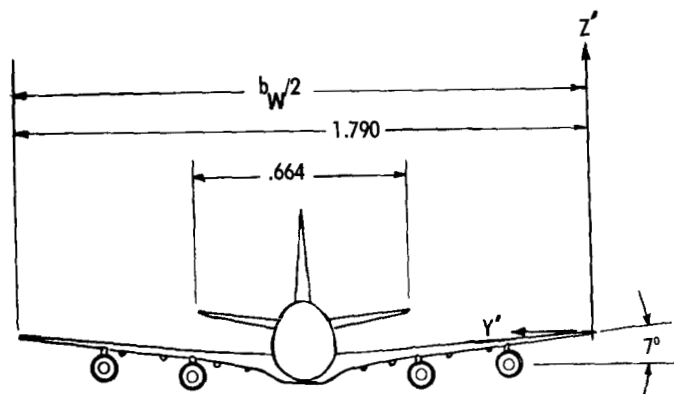
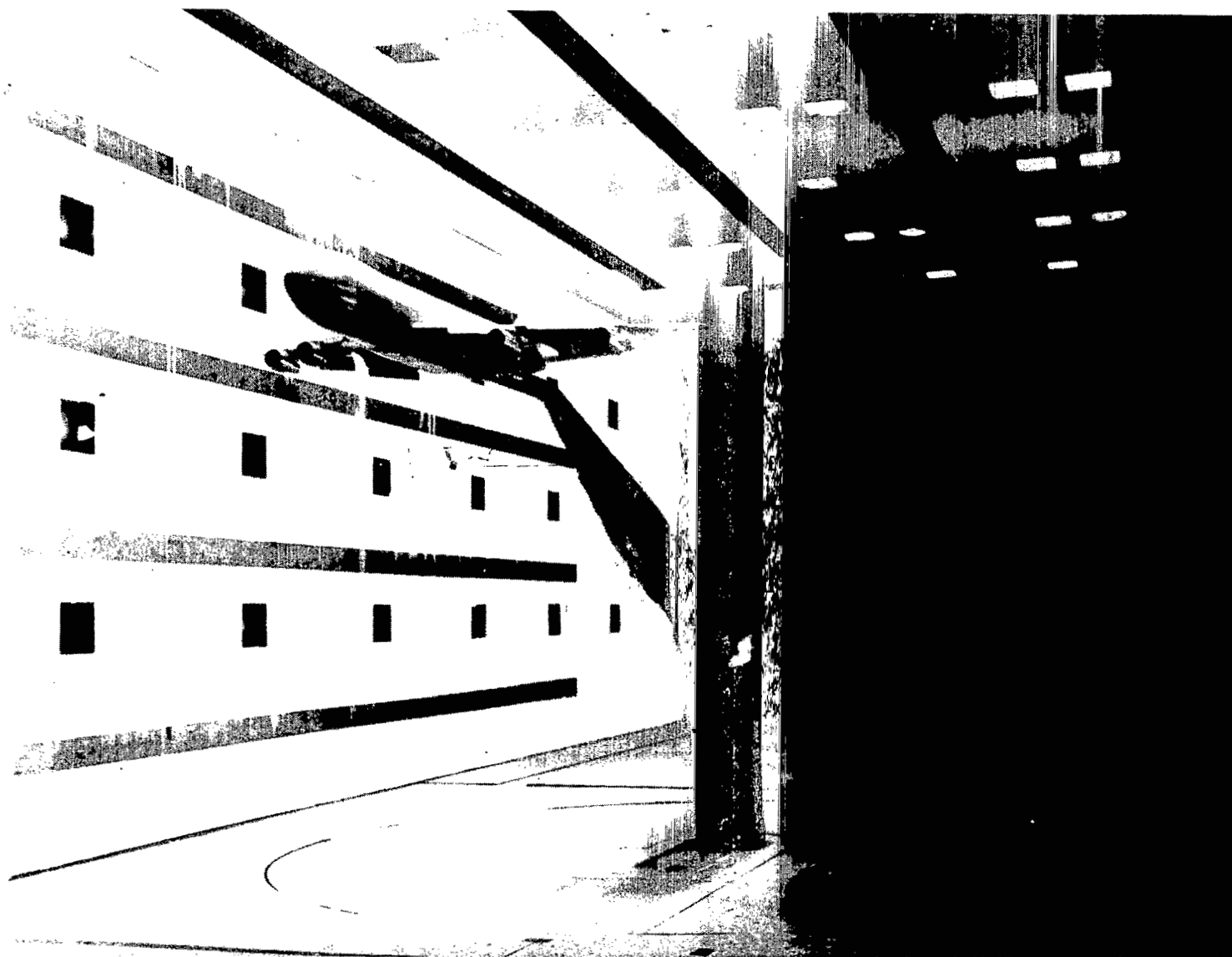


Figure 1.- Three-view sketch of transport aircraft model with flaps retracted. Linear dimensions are in meters.



L-75-2407

Figure 2.- Photograph of transport aircraft model in the Langley V/STOL tunnel.

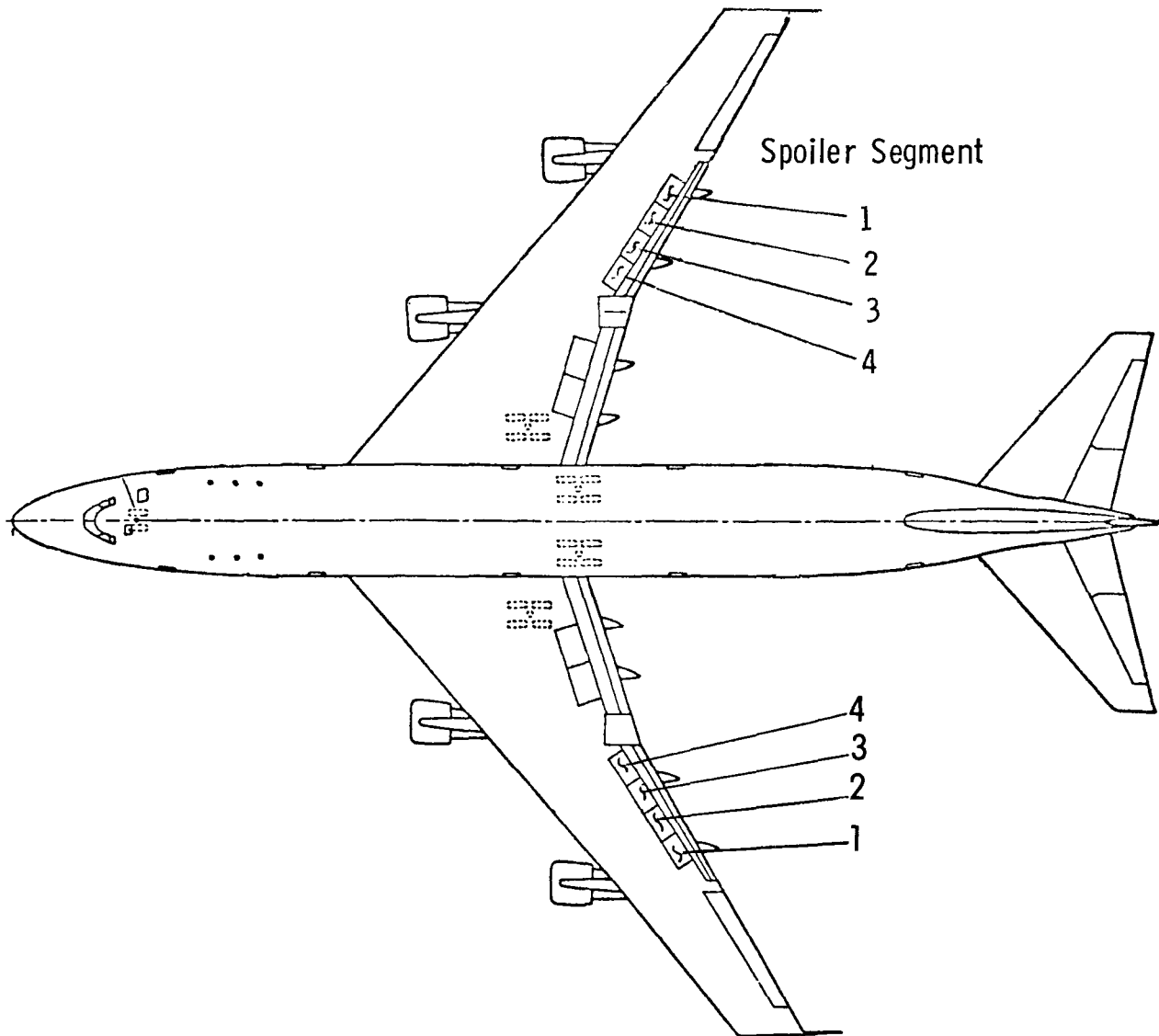
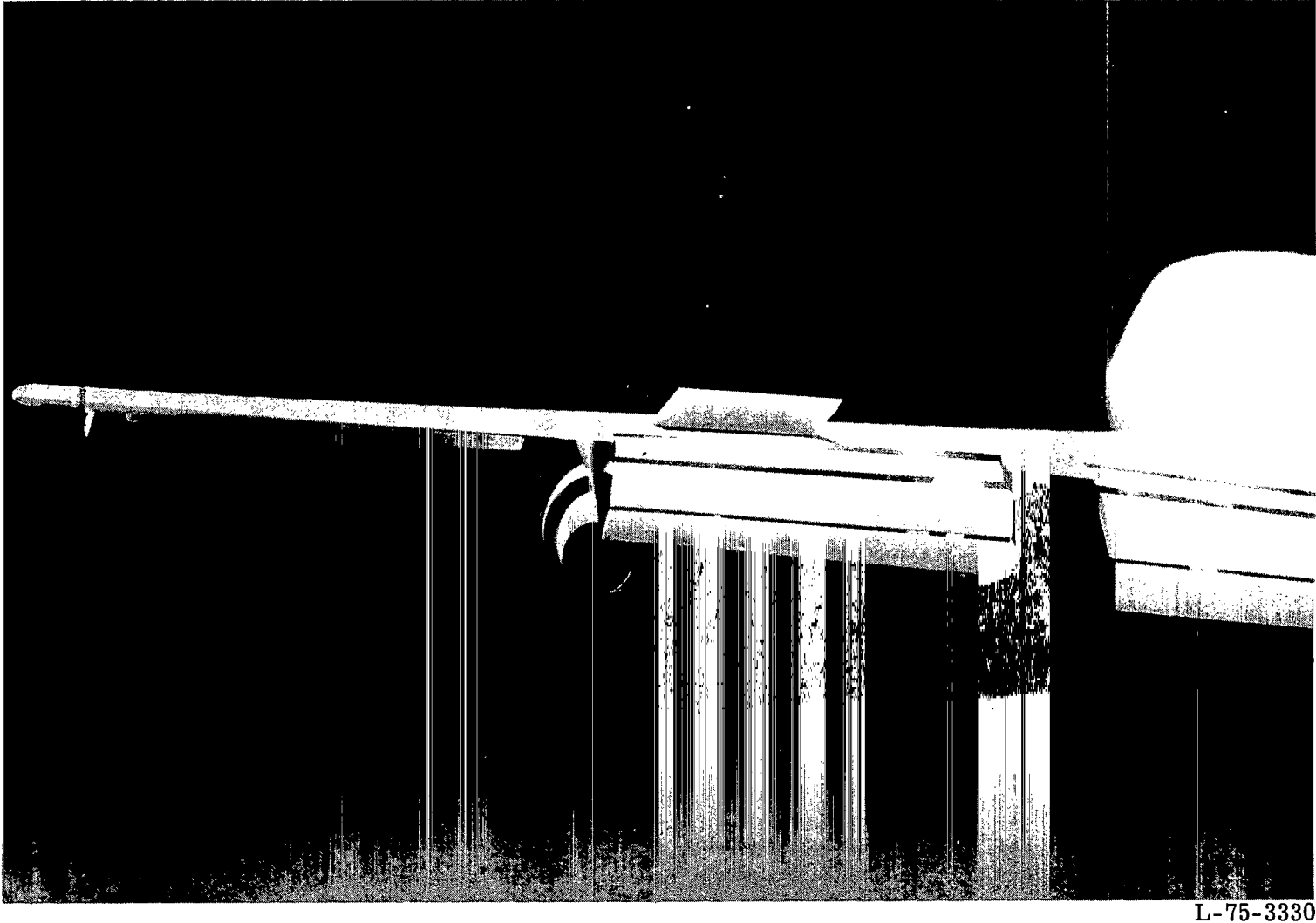
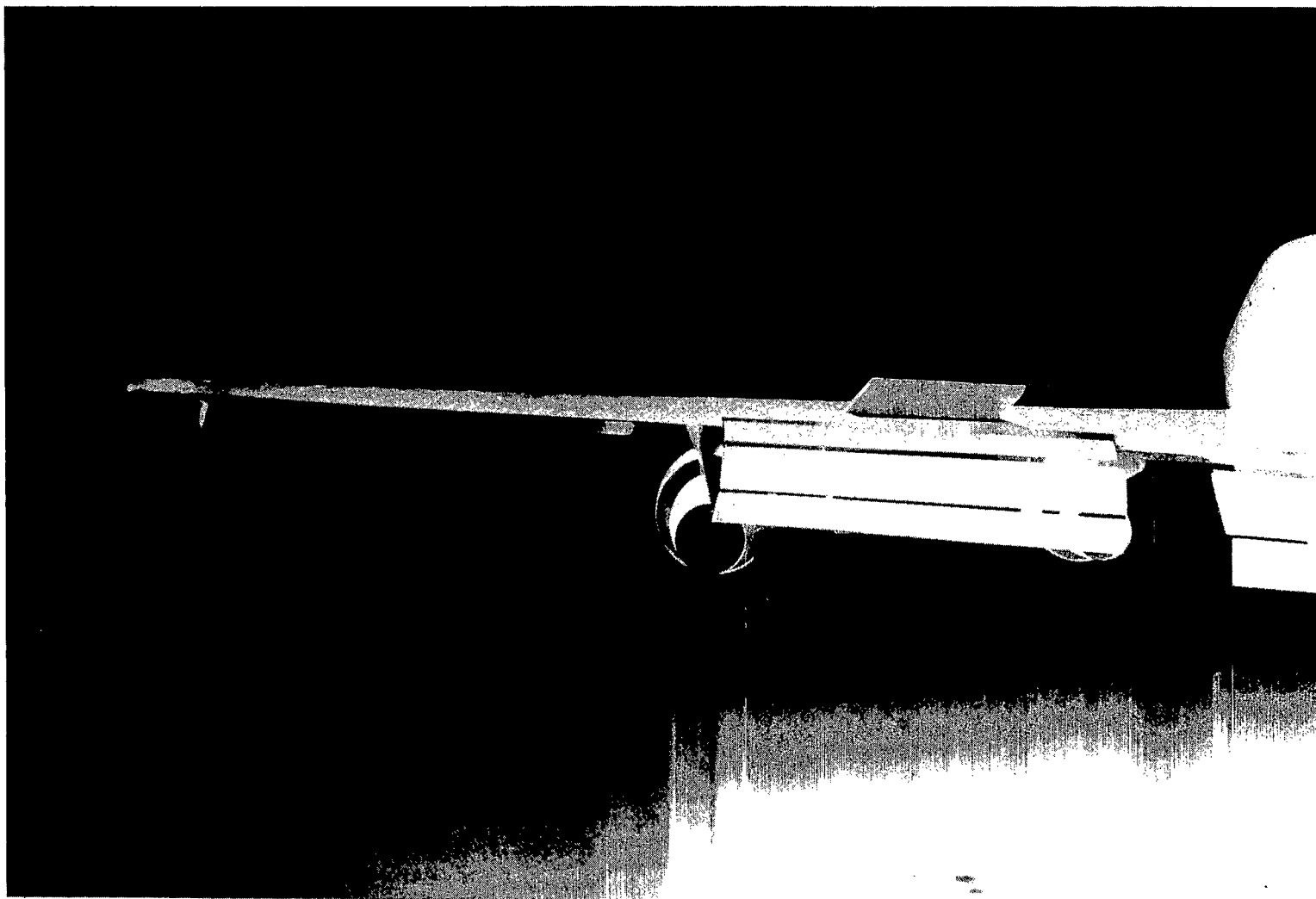


Figure 3.- Sketch of flight spoilers on transport aircraft model.



(a) Spoiler segments 1 and 2 deflected 45° .

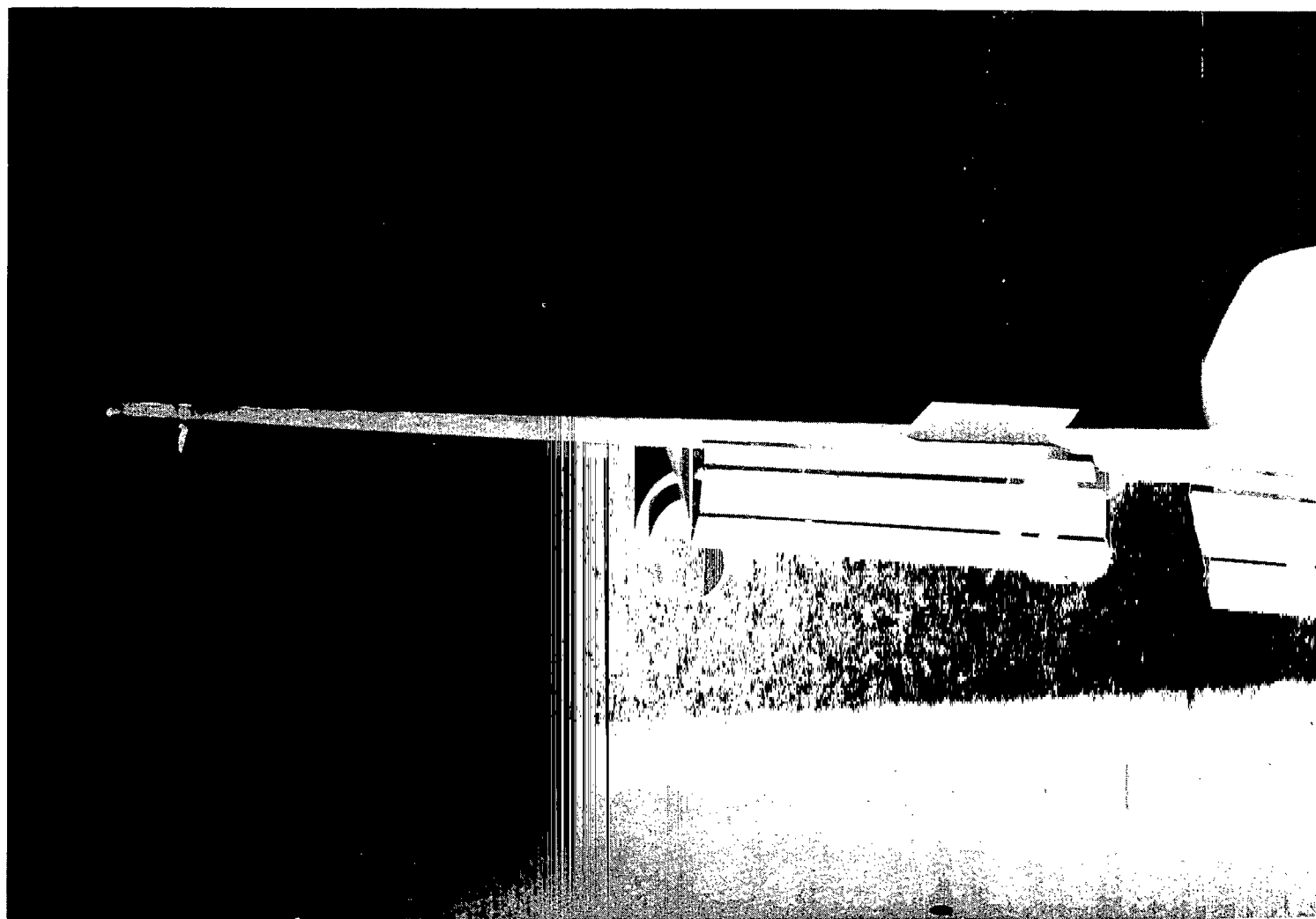
Figure 4.- Photographs of flight spoilers on transport aircraft model.



L-75-3331

(b) Spoiler segments 2 and 3 deflected 45° .

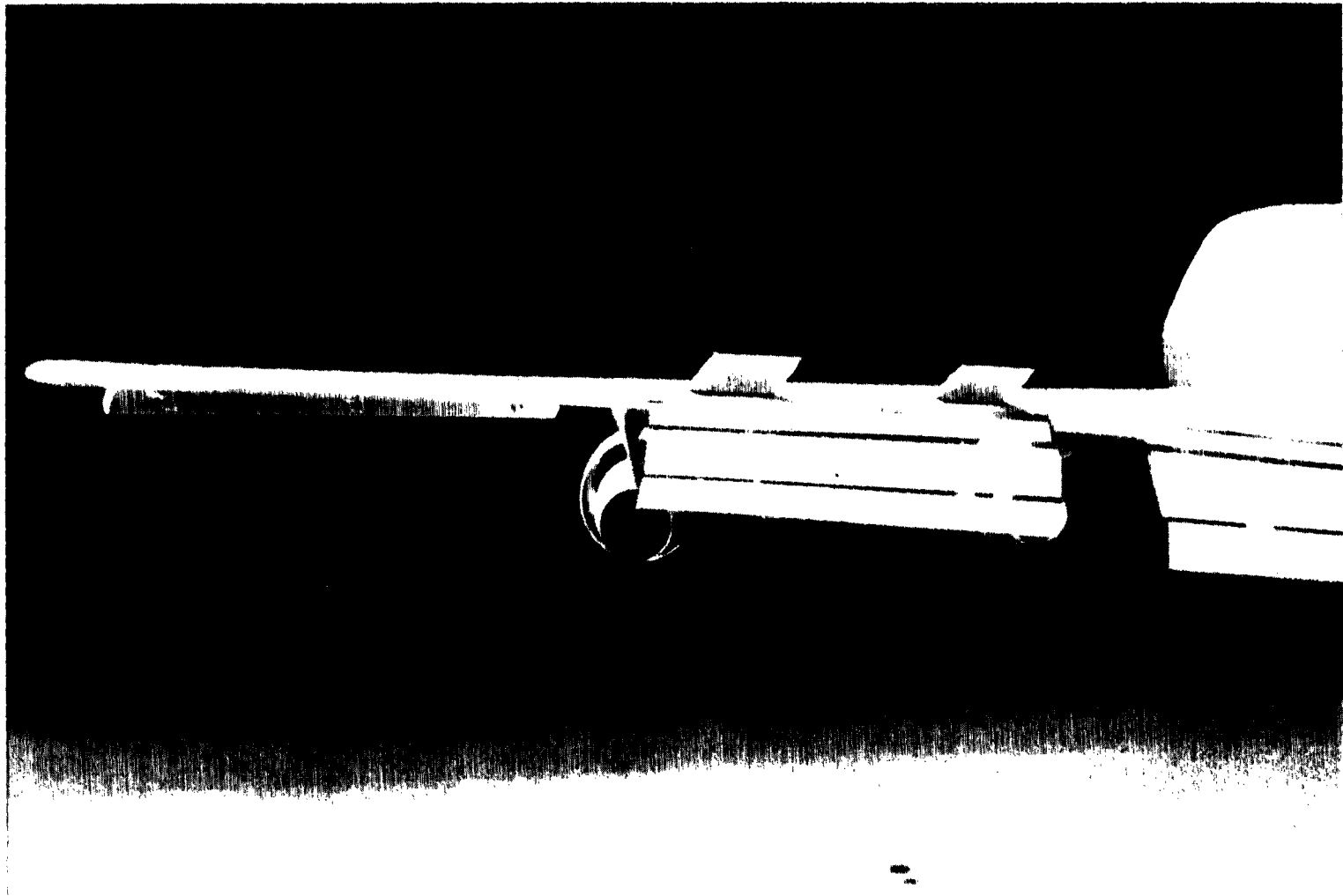
Figure 4.- Continued.



L-75-3337

(c) Spoiler segments 3 and 4 deflected 45° .

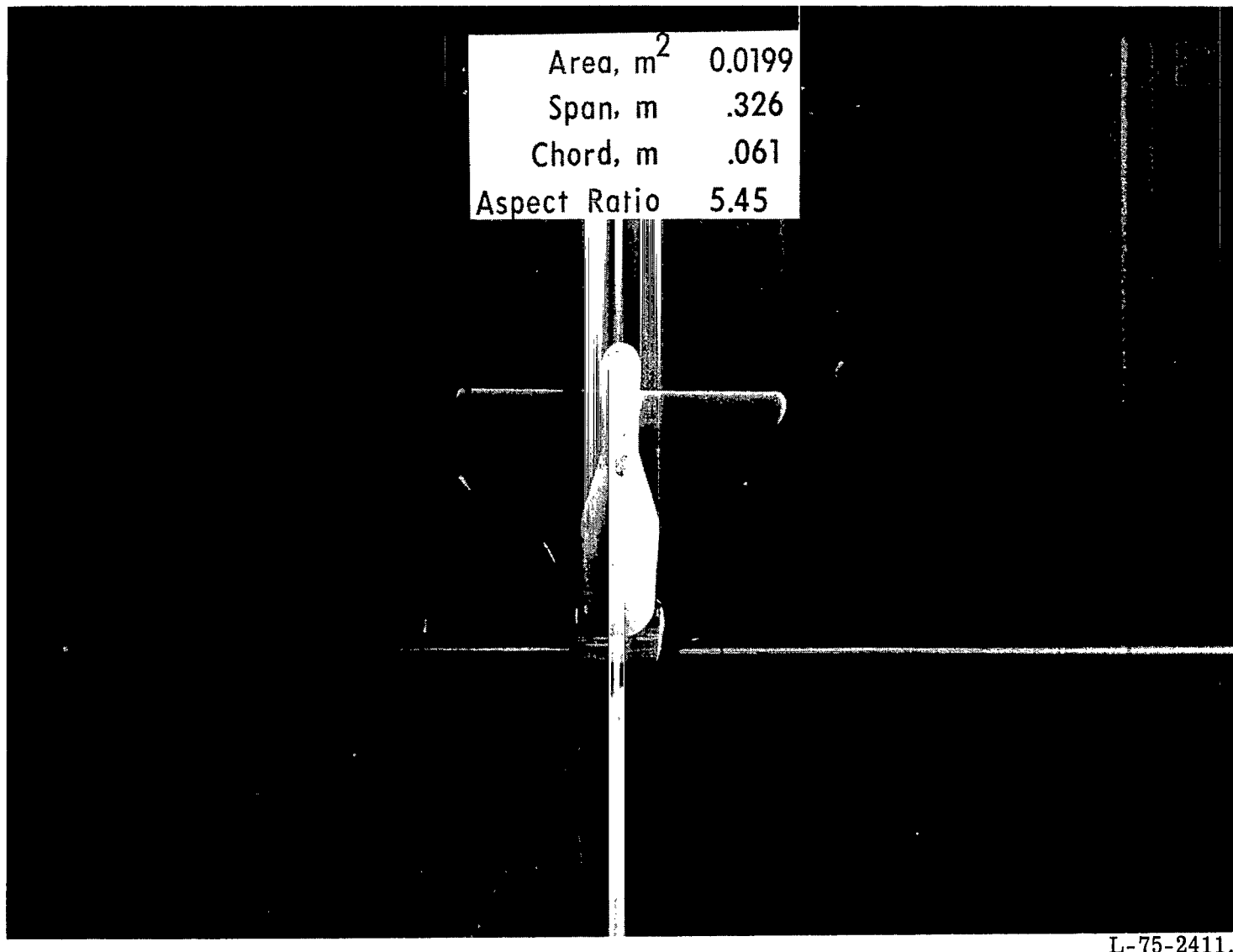
Figure 4.- Continued.



L-75-3333

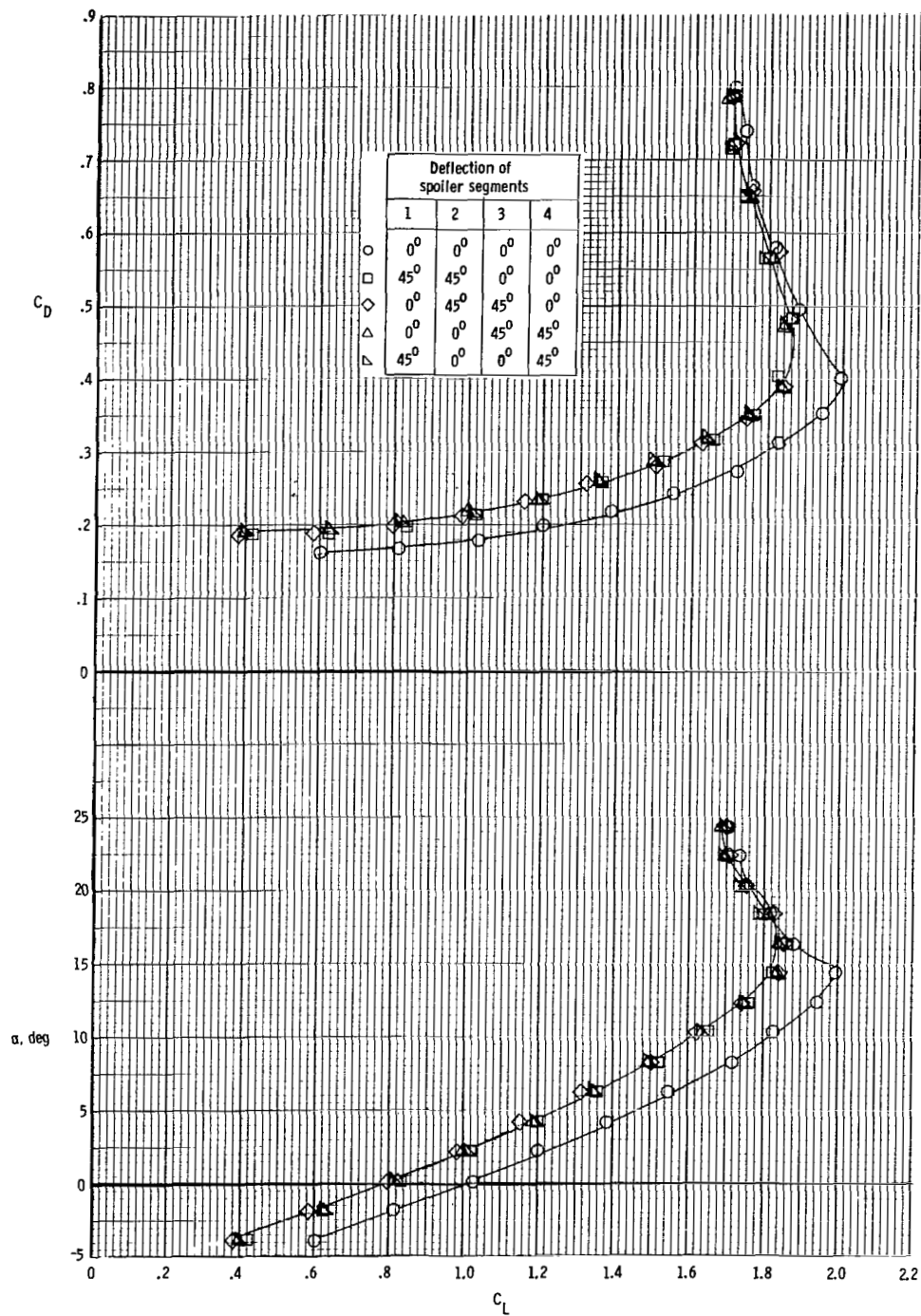
(d) Spoiler segments 1 and 4 deflected 45° .

Figure 4.- Concluded.



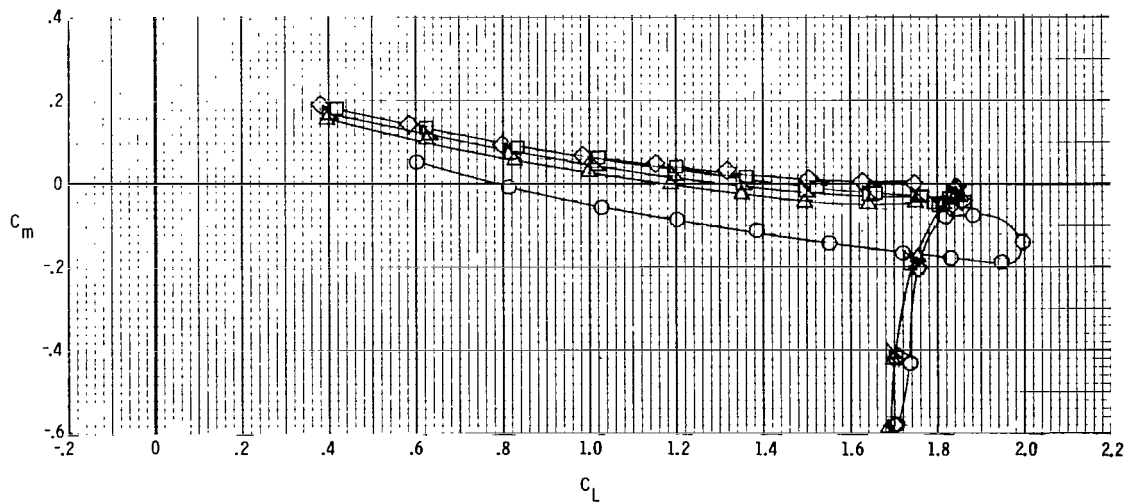
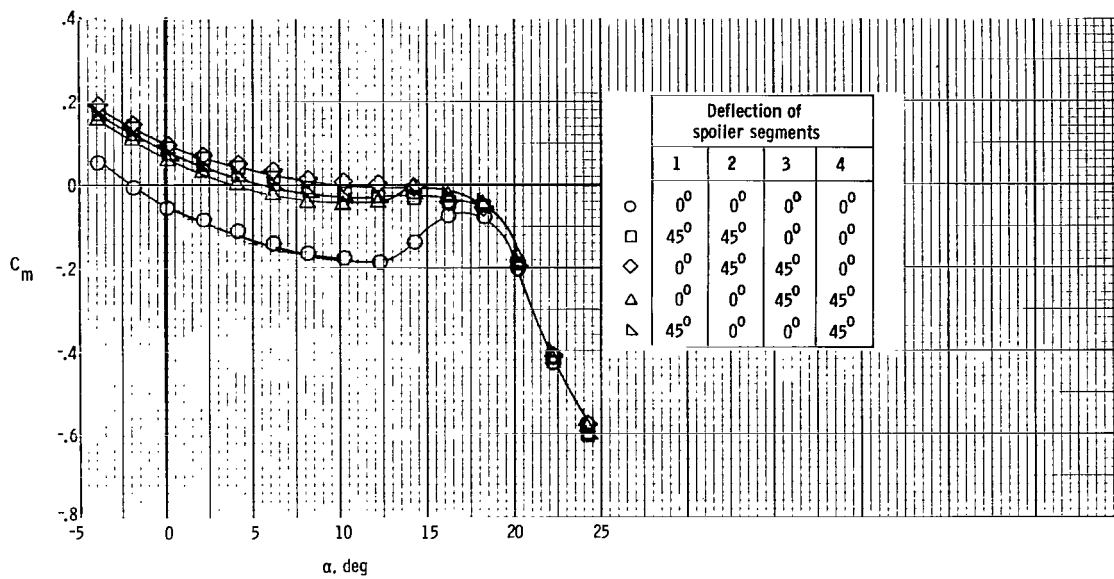
L-75-2411.1

Figure 5.- Photograph and dimensions of unswept trailing wing model on traverse mechanism.
Model has NACA 0012 airfoil section.



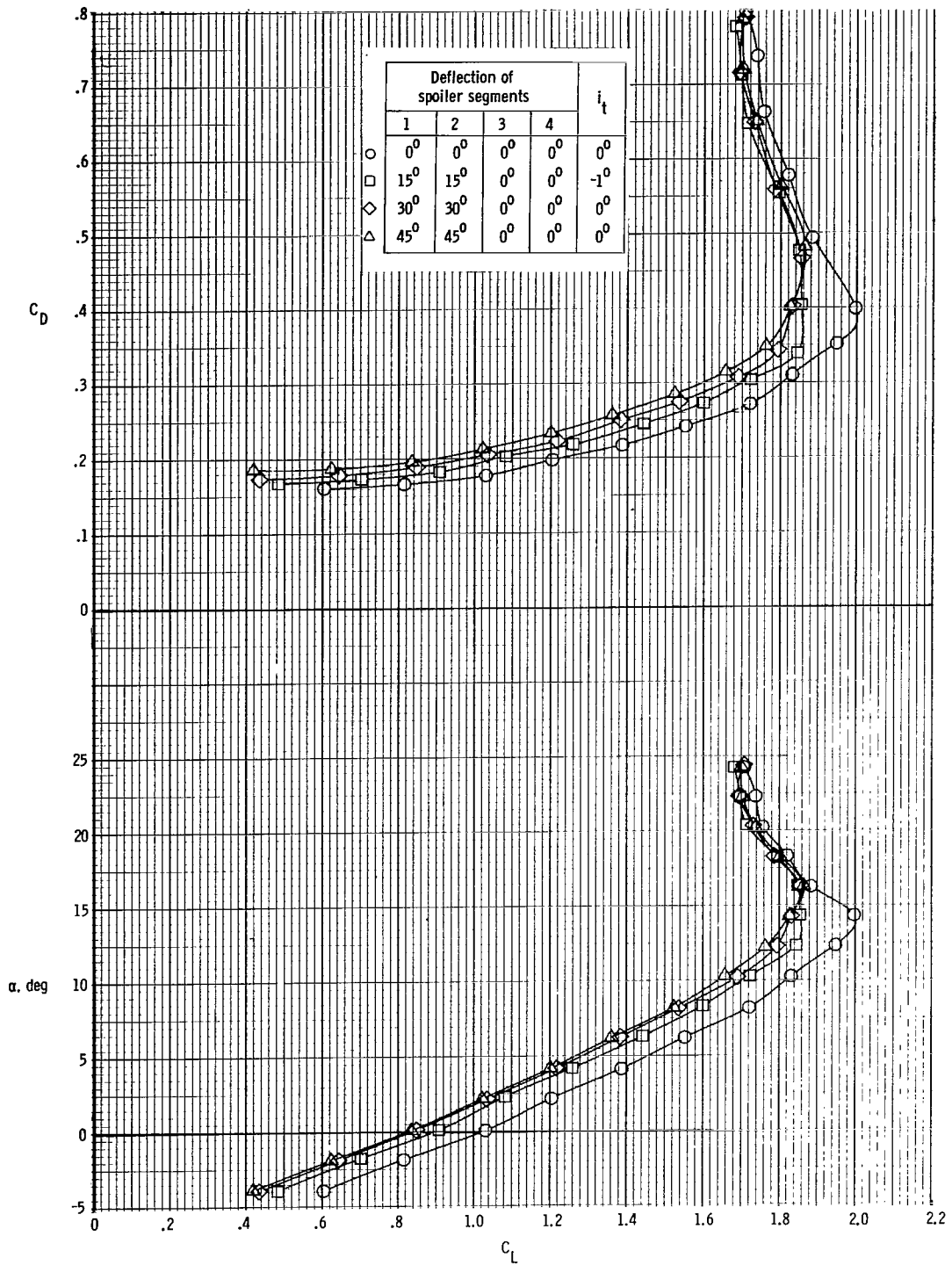
(a) Lift and drag coefficient.

Figure 6.- Effect of flight-spoiler segments 1 and 2, 2 and 3, 3 and 4, and 1 and 4 deflected 45° on longitudinal aerodynamic characteristics of transport aircraft model. $i_t = 0^\circ$; $\delta_{f,i} = 30^\circ$; $\delta_{f,o} = 30^\circ$.



(b) Pitching-moment coefficient.

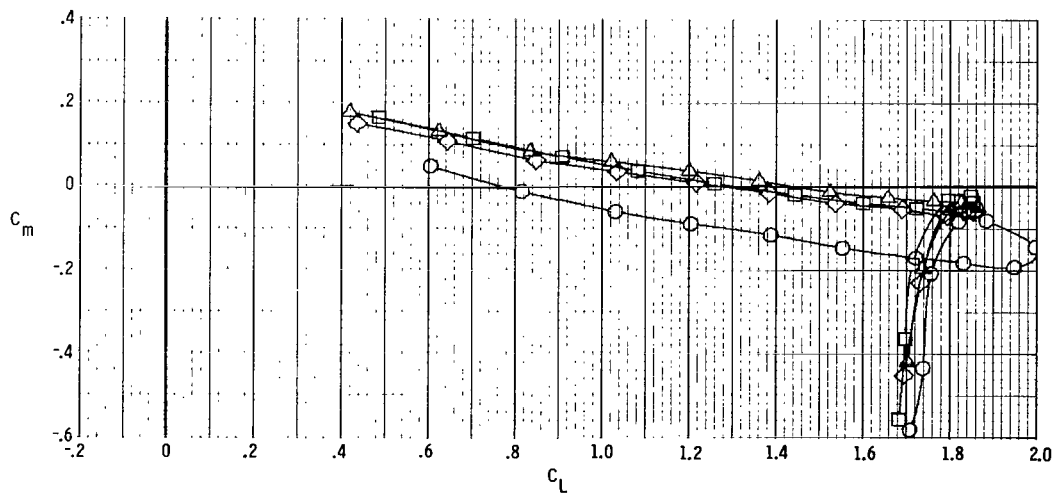
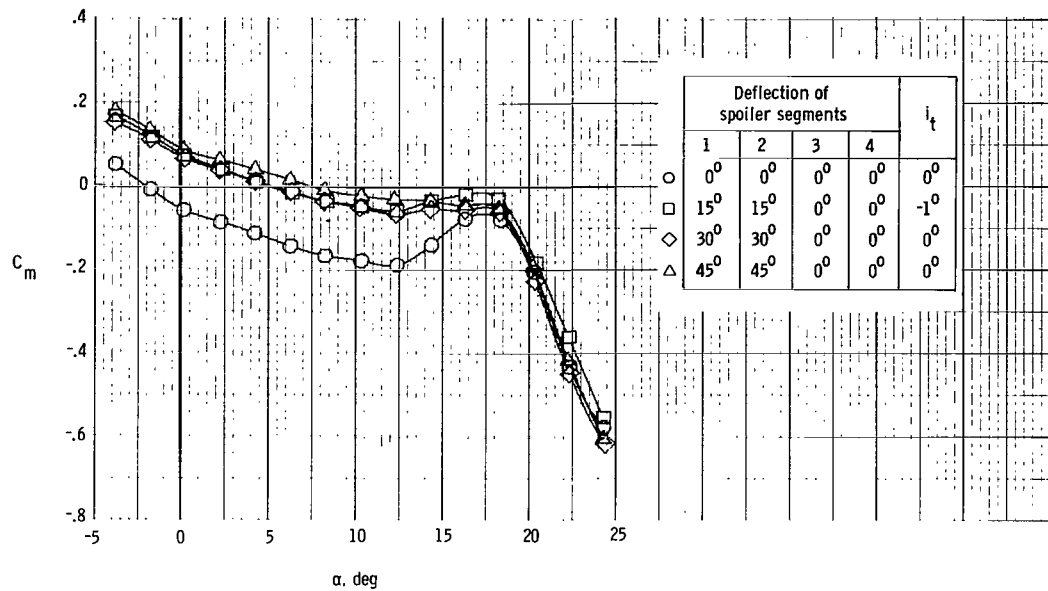
Figure 6.- Concluded.



(a) Lift and drag coefficient.

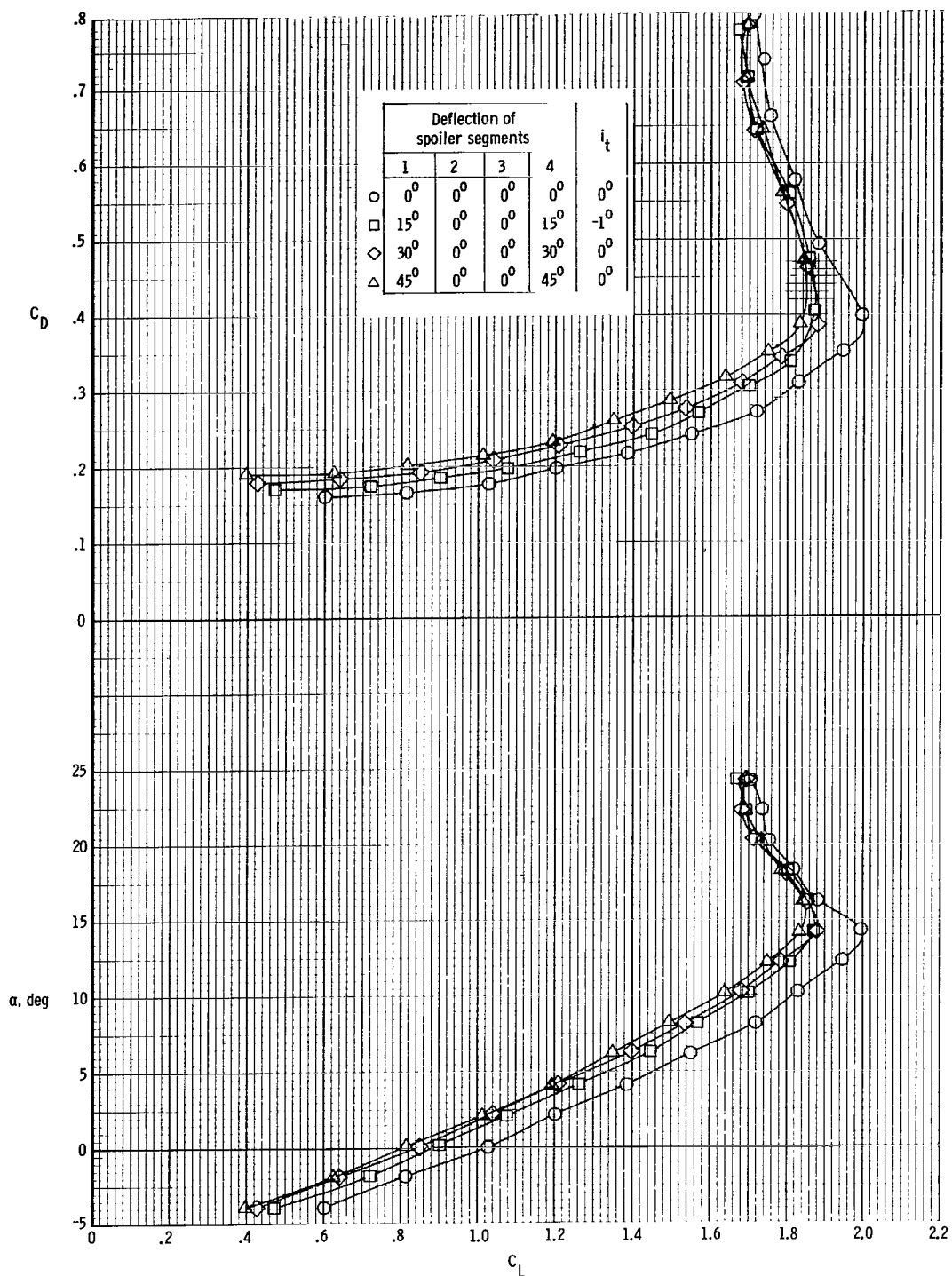
Figure 7.- Effect of deflection angle of flight-spoiler segments 1 and 2 on the longitudinal aerodynamic characteristics of the transport aircraft model.

$$\delta_{f,i} = 30^\circ; \quad \delta_{f,o} = 30^\circ.$$



(b) Pitching-moment coefficient.

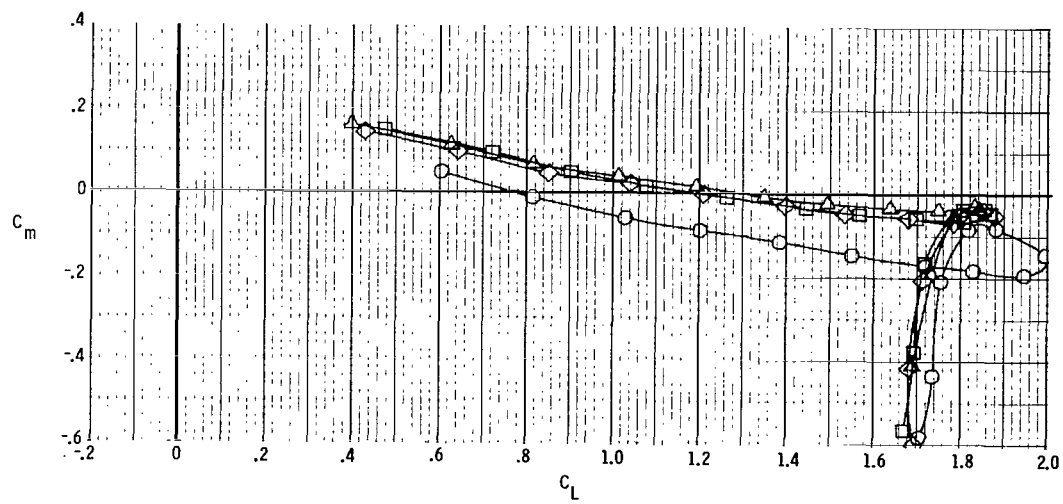
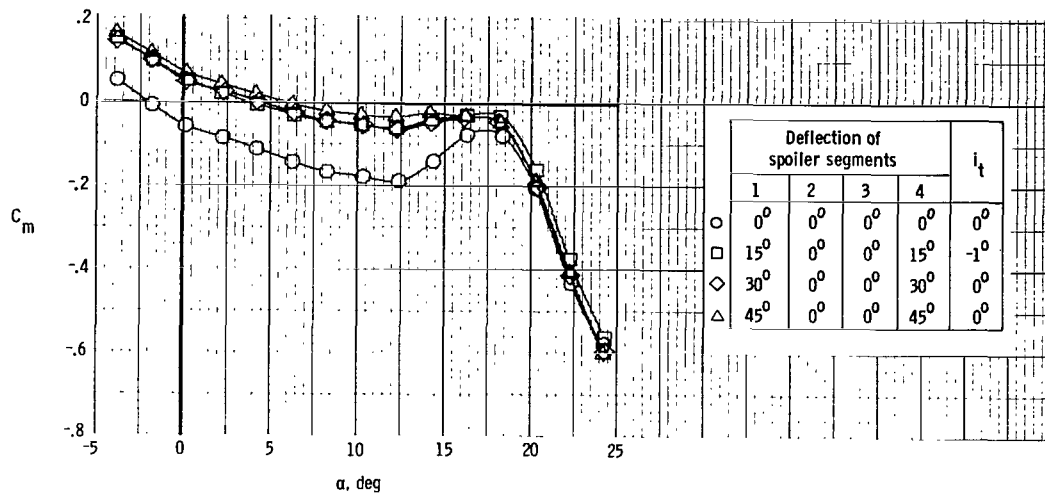
Figure 7.- Concluded.



(a) Lift and drag coefficient.

Figure 8.- Effect of deflection angle of flight-spoiler segments 1 and 4 on the longitudinal aerodynamic characteristics of the transport aircraft model.

$$\delta_{f,i} = 30^\circ; \quad \delta_{f,o} = 30^\circ.$$



(b) Pitching-moment coefficient.

Figure 8.- Concluded.

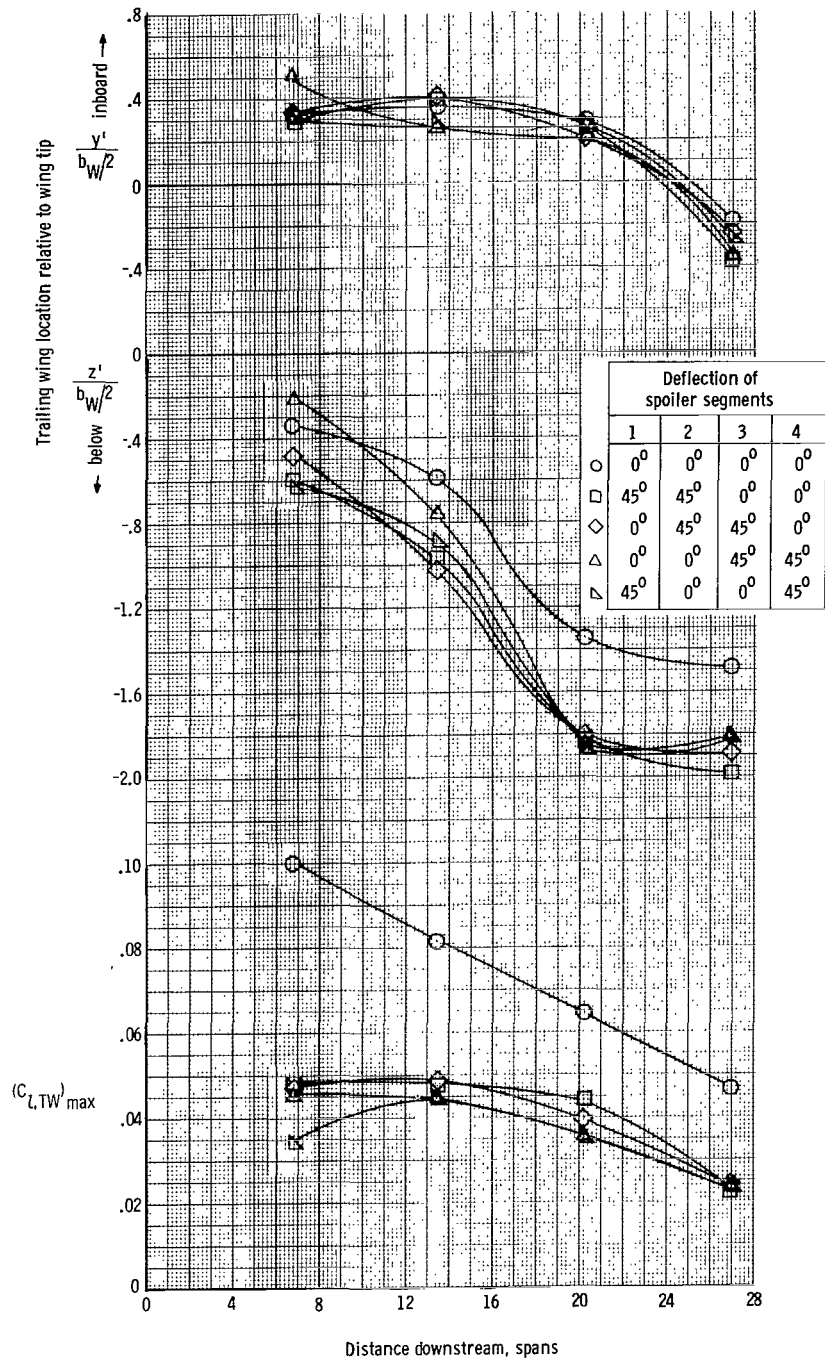


Figure 9.- Variation of trailing wing location and rolling-moment coefficient with downstream distance behind the transport aircraft model (distance given in transport wing spans) with various segments of the flight spoilers deflected 45°. $C_{L,trim} = 1.2$.

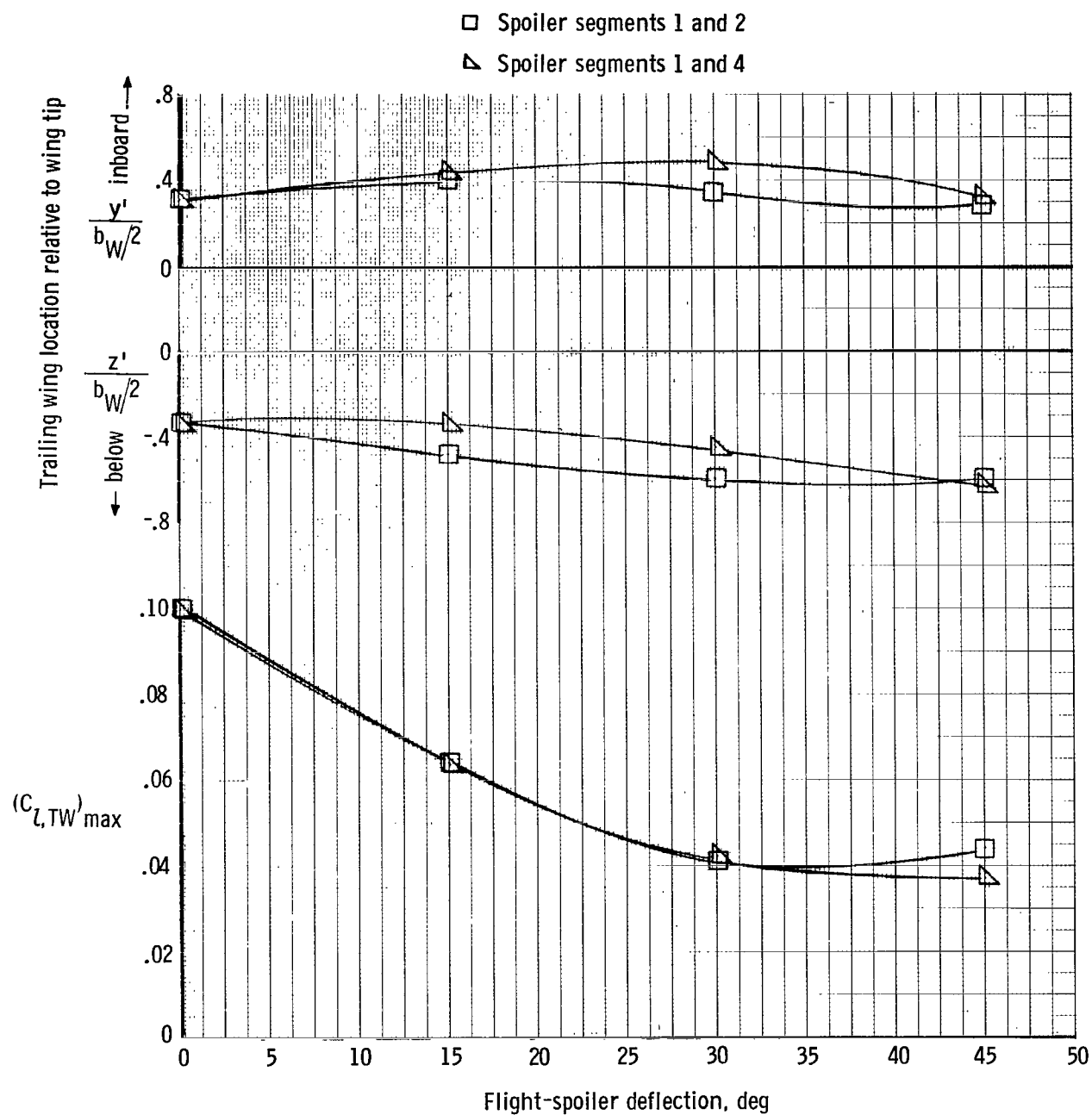


Figure 10.- Variation of trailing wing location and rolling-moment coefficient with flight-spoiler deflection for flight-spoiler segments 1 and 2 and segments 1 and 4. Trailing wing model located 6.7 transport wing spans behind transport aircraft model; $C_{L,trim} = 1.2$.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE \$300

SPECIAL FOURTH-CLASS RATE
BOOK

POSTAGE AND FEES PAID
NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
451



311 001 C1 U A 760213 S00903DS
DEPT OF THE AIR FORCE
AF WEAPONS LABORATORY
ATTN: TECHNICAL LIBRARY (SUL)
KIRTLAND AFB NM 87117

POSTMASTER: If Undeliverable (Section 158
Postal Manual) Do Not Return

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons. Also includes conference proceedings with either limited or unlimited distribution.

CONTRACTOR REPORTS: Scientific and technical information generated under a NASA contract or grant and considered an important contribution to existing knowledge.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities. Publications include final reports of major projects, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

TECHNOLOGY UTILIZATION PUBLICATIONS: Information on technology used by NASA that may be of particular interest in commercial and other non-aerospace applications. Publications include Tech Briefs, Technology Utilization Reports and Technology Surveys.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION OFFICE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D.C. 20546